In collaboration with Capgemini

WORLD ECONOMIC FORUM

From Policy to Practice: Actionable Recommendations for a Commercial Bioeconomy

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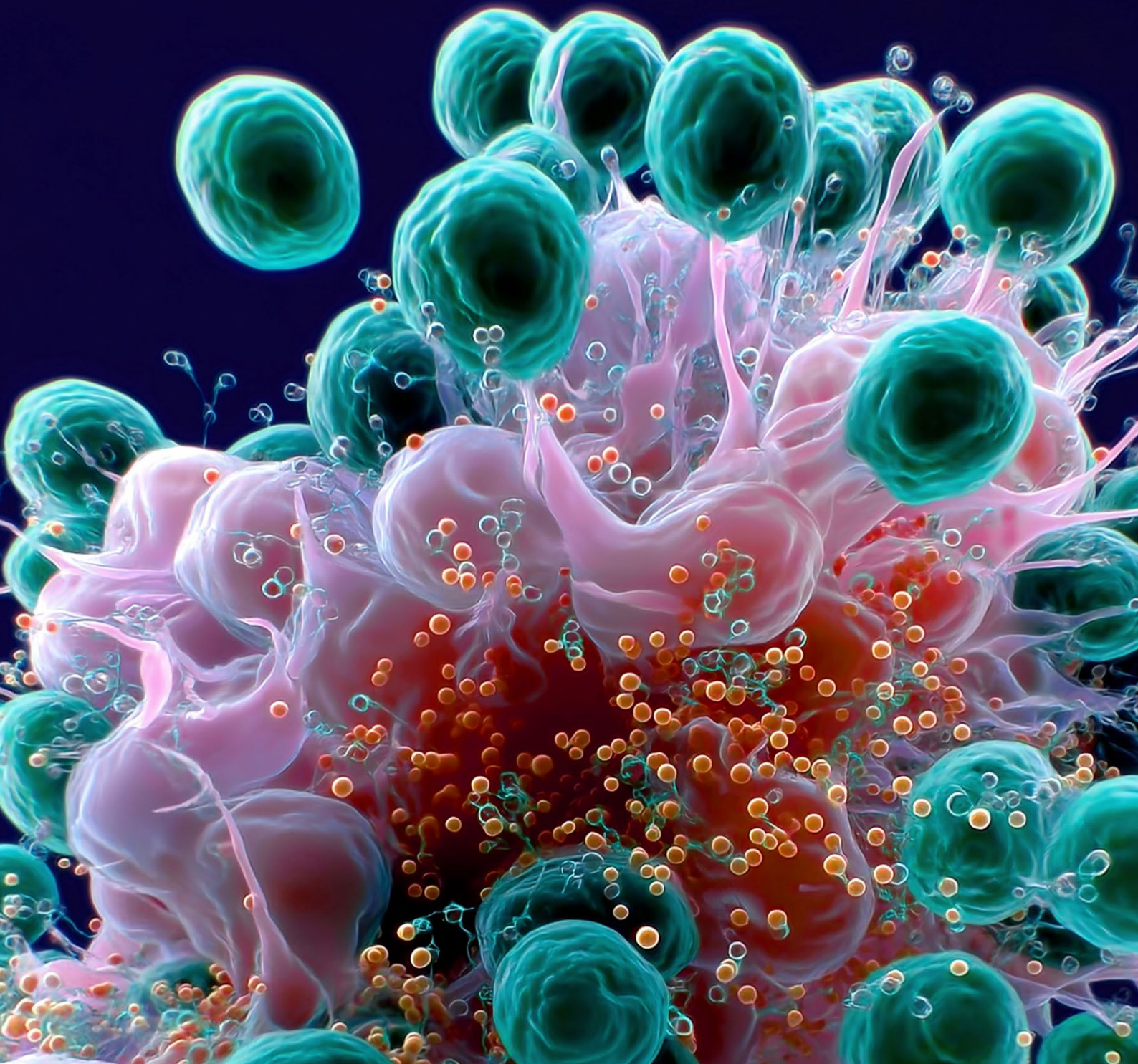

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Foreword

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The bioeconomy represents one of the most profound opportunities of our time – a bridge between innovation and impact, science and society, economic growth and environmental stewardship. Bio-innovation's potential to reshape industries, strengthen domestic supply chains, and create new models of national competitiveness is no longer theoretical. It is real, it is rising and it is ready to be scaled.

Yet the bioeconomy stands at a crossroads. While the pace of technological advancement has been extraordinary, mainstream adoption remains limited. Too often, stakeholders lead with a technology-push approach, driven by scientific possibilities rather than market readiness. To unlock the full potential of bio-innovation, a fundamental shift is needed – one that ensures innovation is not only possible, but also commercially viable, regionally relevant and socially impactful.

Amid rising geopolitical uncertainty, climate instability and economic volatility, governments and industry are under pressure to do more with less – driving inclusive growth, promoting innovation and cultivating resilience despite limited resources. In this new normal, bio-innovation must not be perceived as "nice to have", but as a strategic imperative. A well-developed bioeconomy can be a powerful catalyst for new economic models, future-ready supply chains and national competitiveness – while advancing global sustainability.

Across the globe, over 50 national strategies are focused on accelerating the bioeconomy. But strategy alone is not enough. Coordinated, actionable frameworks that deliver clear outcomes and remove barriers are needed urgently. This means policy environments that favour a market-pull dynamic – supported by compelling fiscal incentives, trustworthy regulation and tailored financial support mechanisms that enable breakthroughs to scale with speed and responsibility.

Together with our global partners, the World Economic Forum's Bioeconomy Initiative has developed this Policy Framework as a call to action. Drawing from real-world success stories, it offers actionable recommendations that guide policy-makers and industry leaders to cohesive, outcome-driven implementation. Effective policy is a powerful driver of transformation, and sharing global best practices is essential to unlocking scalable, locally adapted solutions. Taken together, the recommendations presented herein aim to help regions achieve more amid rising geopolitical uncertainty.

The Forum's Bioeconomy Initiative, in close collaboration with Capgemini and dsm-firmenich, brings together a community of government, academic and industry leaders, united by a shared ambition: to accelerate the transition toward a commercial, scaled and technology-driven bioeconomy. The bioeconomy is no longer a distant vision. But success depends on bold leadership and collaborative efforts across borders, sectors and disciplines. Now is the time to act with clarity and purpose: to design policy that moves beyond strategy documents to enable innovation, accelerate adoption and ensure the bioeconomy becomes a cornerstone of sustainable economic growth and global competitiveness. Let's not just imagine what's possible tomorrow. Let's shape it together today.

Executive summary

Translating national strategies into actionable outcomes has never been more important.

The public sector has taken notice: with over 50 national strategies aimed at accelerating regional bioeconomies, bio-innovation has quickly risen to the top of national agendas. Conveying what should be done, national bioeconomy strategies often omit guidance for implementation. With current global trade uncertainties, the urgency around translating national strategies into actionable outcomes has never been more important. To capitalize on the opportunities presented by bioeconomy strategies, a set of actionable, government-driven policy recommendations aimed at bolstering domestic supplies, local innovation and manufacturing capabilities are needed.

The Forum's Bioeconomy Framework provides policy-makers with a practical roadmap to guide the bioeconomy's commercial evolution from a "technology push" to a market pull. This framework puts forward a series of 14 actionable recommendations across four categories, spanning:

1. Regulation
2. Incentives
3. Financing
4. Access and education

The recommendations outlined in this framework are interconnected and synergistic. They are designed to provide more targeted and tailored support for early-stage R&D throughout the scaling process. By strategically implementing combinations of the recommendations herein, this framework aims to deliver a much-needed stimulus for scalable bio-innovation. Taken together, the overall goal of the framework is to accelerate the global transition to a bio-based economy where domestic supplies and capabilities are bolstered, and commercial practices are primed to meet evolving societal and planetary needs. While governments cannot drive this shift alone, they play a crucial role by incentivizing and spearheading broader catalysts for change.

Introduction

The bioeconomy is poised to generate significant economic impact.

Policy frameworks are essential tools that offer structured and adaptable recommendations for decision-making and implementation. They provide a strategic blueprint that individual governments and jurisdictions can tailor to address emerging challenges and advance national goals. By promoting consistency and harmonization, these frameworks help balance innovation, safety and public interest. Policy frameworks serve as the foundation for supportive enablers that drive systematic progress across various fields and industries.

Historically, policy frameworks have guided the successful commercial development and deployment of emerging technologies. For instance, the policy frameworks established during 2010 in China around electric vehicles (EVs) and battery technology combined government subsidies, infrastructure development and emissions regulations.[1] This multifaceted approach catalysed China's emergence as the world's largest EV market today and a leader in battery innovation, driving corresponding cost reduction globally.

Bio-innovation is evolving commercially by integrating life sciences with convergent technological advances to reshape industries, societies and ecosystems. As bio-innovation becomes increasingly commercialized, it is poised to generate significant economic impact, transforming the products, services and systems that underpin the global economy. With applications spanning healthcare, agriculture, energy and manufacturing, engineering biology offers wide-reaching potential: from improving medical treatments to developing sustainable materials, renewable energy and resilient food systems.[2] Recognizing its systemic value, governments worldwide are implementing strategies to develop robust and competitive bioeconomies; since 2010 alone, more than 50 national strategies dedicated to the bioeconomy have been published.[3]

However, for collective ambitions to translate into tangible economic outputs, strategy documents must be transformed into focused, concrete action.

Why a thriving commercial bioeconomy matters now

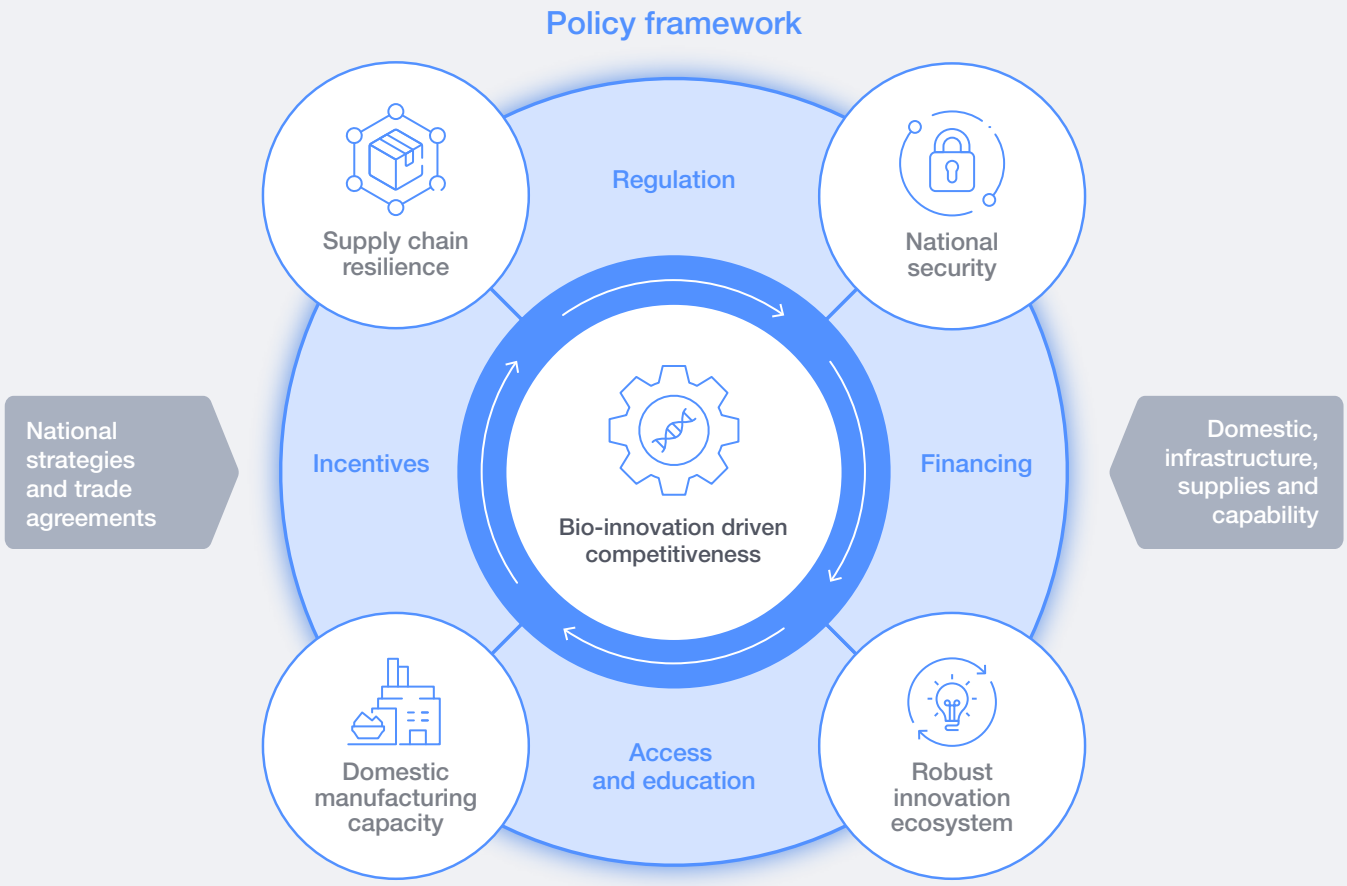
The global bioeconomy is expanding rapidly and already contributes substantially to GDP (gross domestic product).[4,5] Owing to lengthy timelines and costs associated with commercialization, bio-innovation has a long way to go before becoming a viable commercial tool across industries.

Beyond driving economic growth and industrial transformation, the bioeconomy offers sustainable industrial alternatives and represents additional avenues for national supply chain resilience and competitiveness. Investing in local supply chains enables governments and businesses to diversify sourcing, bolster domestic innovation, and ensure a steady supply of critical goods and services, especially in key sectors such as healthcare and defence. These investments not only strengthen resilient domestic production but also serve as valuable drivers of economic growth.

The bioeconomy as a tool to bolster national resilience during trade uncertainty

Trade uncertainties can significantly disrupt non-domestic supply chains, driving nations to bolster domestic manufacturing capabilities and prioritize innovation. During trade instability, many countries seek to reduce reliance on foreign sources for critical materials such as pharmaceuticals, fuels and food. Strengthening domestic biomanufacturing capabilities enhances a nation's ability to respond to pandemics, bioterrorism and other biological threats.

FIGURE 1 | **Adaptive policy framework for national strategies**



Note: The recommendations within this policy framework span interrelated and synergistic categories set in the context of national strategies and capability. As such, individual recommendations may not be applicable in every regional context but can be selected as needed.

Countries that lead in bio-innovation gain a competitive advantage in global markets (Figure 1). The US, for example, demonstrates this through the international success of biotech companies like Regeneron and Eli Lilly. Investing in biotechnology, biomanufacturing and bio-based materials stimulates the growth of new industries, creates jobs, and expands trade opportunities, driving economic growth and national resilience. Nations with strong bioeconomies also benefit strategically in food production through innovations such as more self-sufficient crops, cultivated meat and precision fermentation. These outputs and approaches improve efficiency, enhance nutritional value and increase crop resilience – critical advantages in the face of climate change. Investing in bio-innovation domestically strengthens supply chains and enhances local food security.

Additionally, the bioeconomy offers significant potential for generating value by converting biowaste into valuable products, promoting the trade of bio-refined goods (Box 1). These processes reduce post-harvest losses, improve environmental sustainability, and boost income for households and businesses, particularly in urban and peri-urban areas.

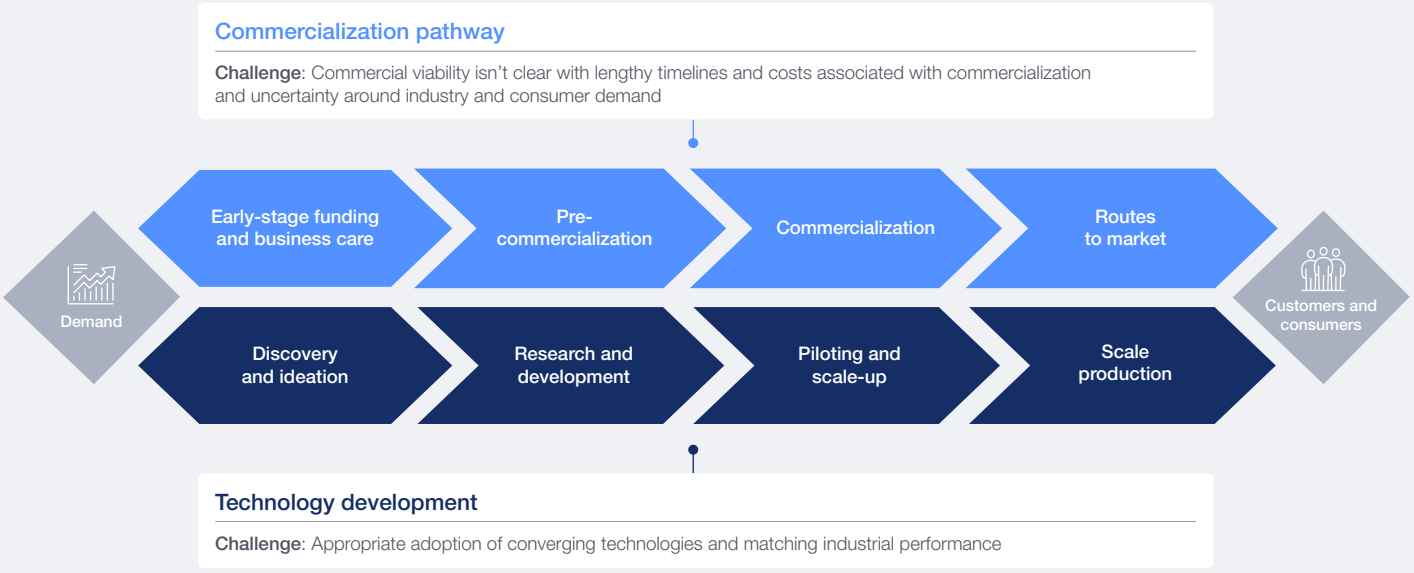
BOX 1 | **Transforming biological resources into valuable products**

BioInnovate Africa is a programme under the International Centre of Insect Physiology and Ecology (icipe) that supports the development of a bioeconomy in Eastern Africa. It funds and mentors innovators working on R&D projects to transform biological resources into valuable products, promoting regional integration and sustainable development.[6]

Coalescing around a path forward together

Given the significant opportunities related to national security, competitiveness, food security and supply chain resilience, governments are more motivated than ever to translate national strategies into key drivers of economic growth. However, the path for governments to drive such transformation and implement strategies that translate into thriving, commercially relevant bioeconomies remains unclear.

FIGURE 2 **Commercialization pathways that bridge technology to market**



Note: The commercialization and technology development pathways must be considered hand-in-hand to avoid a technology push, which risks technologies emerging from the bench with limited market traction. The policy framework recommendations bridge this gap by illustrating how governments can drive transformation and implement strategies to accelerate commercially relevant biosolutions.

Moving from policy ambition to commercially viable and globally competitive bioeconomies requires more than strategy alone. The Forum's Bioeconomy Policy Framework provides a practical roadmap to accelerate this transition, shifting from a technology push model, where innovations struggle to gain market traction, to a market pull environment driven by active industry and consumer demand (Figure 2). By bridging this gap, governments can better harness the bioeconomy's full potential as a driver of national security, economic growth and resilience, while laying the foundation for innovation-driven industries and a future-oriented society.

A word on the framework

The framework is designed to be simple, actionable and adaptable. It puts forward 14 recommendations across four key categories: regulation, incentives, financing, and access and education. Each recommendation is illustrated with a real-world example demonstrating how they are applied (Table 1). While the framework provides a comprehensive guide, it is not a one-size-fits-all solution: the mix of recommendations should be carefully tailored to each country's regional context and national priorities.

TABLE 1 | **Policy framework: actionable recommendations for a commercial bioeconomy**

Recommendation category 1: Technology-informed and accessible regulation to drive commercialization		
Country/region	**Recommendation**	**Example**
 **EU**	1. Greater access to testbeds for commercial bio-innovation	Test Farms empowers start-ups and individuals with groundbreaking agritech solutions to test and validate their products and services on real farms.[7]
 **UK**	2. Streamlined regulatory pathways designed for purpose	The UK's Regulatory Innovation Office (RIO)[8] aims to streamline regulation that drives commercialization.
 **Japan**	3. Embed and empower technical experts in regulation-making	Japan's SciREX Program promotes policy "coevolution" based on the dialogue between government policy-makers and SciREX researchers.[9]
 **Israel**	4. Greater exposure to regulation-making	The Israel Innovation Authority's Disruptive Innovation Program[10] provides awardees with direct and ongoing support from the Israeli Ministry of Health to navigate and facilitate regulatory processes.
Recommendation category 2: Delivering a market-pull bioeconomy through government-instituted incentives		
Country/region	**Recommendation**	**Example**
 **China**	5. Incentivize early adopters through targeted tax credits	China offers various tax incentives, including preferential rates and deductions, to encourage corporations, especially those in biotechnology and other high-tech sectors, to scale innovation and R&D.[11]
 **Canada**	6. Direct incentives for consumers to adopt bioproducts	Aimed at helping Canadian homeowners make their homes more energy-efficient, the Greener Homes Grant offers up to CAD 5,000 (Canadian dollars) to cover the cost of eligible retrofits.[12]
 **Zambia**	7. Government-supported programmes for large corporations to beta test and scale bio-innovation	Sunbird Bioenergy's ethanol project in Zambia has received government support through a blended ethanol programme and other incentives and aims to produce 120 million litres of fuel-grade ethanol annually.[13]
Recommendation category 3: Blended financing that is government-driven and tailored for commercializing bio-innovation		
Country/region	**Recommendation**	**Example**
 **Singapore**	8. Increase the use of blended and creative financing to balance risk between public and private funds and enhance overall investment	In Singapore, the government partners with private sector investors to invest in innovative, Singapore-based deep tech start-ups that have strong potential to scale globally.[14]
 **US**	9. Government provision of larger tranches of funding earlier in a company's life cycle	The Advanced Research Projects Agency for Health (ARPA-H) has provided $25 million in funding for a series A company, Cellino, for their next generation, ultra-scalable biomanufacturing platform.[15]
 **Germany**	10. Government funding that is flexible and right-sized to bio-innovation	The Federal Agency for Disruptive Innovation (SPRIN-D) offers flexible financing timelines tailored to the unique needs of disruptive innovation.[16]
 **India**	11. Increased government funding for domestic manufacturing infrastructure	The Department of Biotechnology (DBT) has outlined funding mechanisms to support the establishment of biomanufacturing hubs in India, aimed at setting up infrastructure for pilot-scale production, process optimization and commercialization of bio-based products.[17]
Recommendation category 4: Bolstering bioeconomy education and reskilling with innovation ecosystems		
Country/region	**Recommendation**	**Example**
 **Brazil**	12. Government-funded programmes explicitly aimed at bioeconomy education and reskilling	The National Council for Scientific and Technological Development (CNPq) and the Brazilian National Service for Industrial Training (SENAI) fund vocational training programmes in biofuels, biomaterials and agribiotech, and builds technical training centres for bioeconomy workforce development.[18]
 **Thailand**	13. Sustained investment in bio-focused regulatory expertise	The International Service for the Acquisition of Agri-biotech Applications (ISAAA) has an intensive training programme on agribiotech biosafety regulation and effective communication.[19]
 **South Korea**	14. Investing in innovation ecosystem networks	South Korea's Bio-Great Transformation Strategy seeks to integrate 20 bioclusters nationwide, promoting collaboration and infrastructure sharing.[20]

1 Regulation

Accessible, expert-informed regulation is key to accelerating commercialization and scaling bio-innovations responsibly.

Regulation plays a critical role in driving commercialization by reducing uncertainty, mitigating risk and establishing clear standards for scaling emerging technologies. Regulatory frameworks set technical and safety standards, ensuring interoperability, product reliability and consumer trust. As a result, industries that comply with standardized regulations tend to scale faster as both businesses and consumers adopt new products with greater confidence.

Regulation also provides legal and safety clarity, helping to reduce financial and operational risks for companies and investors. With well-defined regulatory pathways in place, investors are more inclined to provide funding support for the commercialization of new technologies.

When it comes to the bioeconomy, regulation shapes and sets the precedent for how bio-based industries develop and bring new products, services, processes and tools to market. While regulation is a vital tool for advancing innovation, investment and commercialization, the relationship between bio-innovation and regulation remains complex. Some of the more significant challenges include:

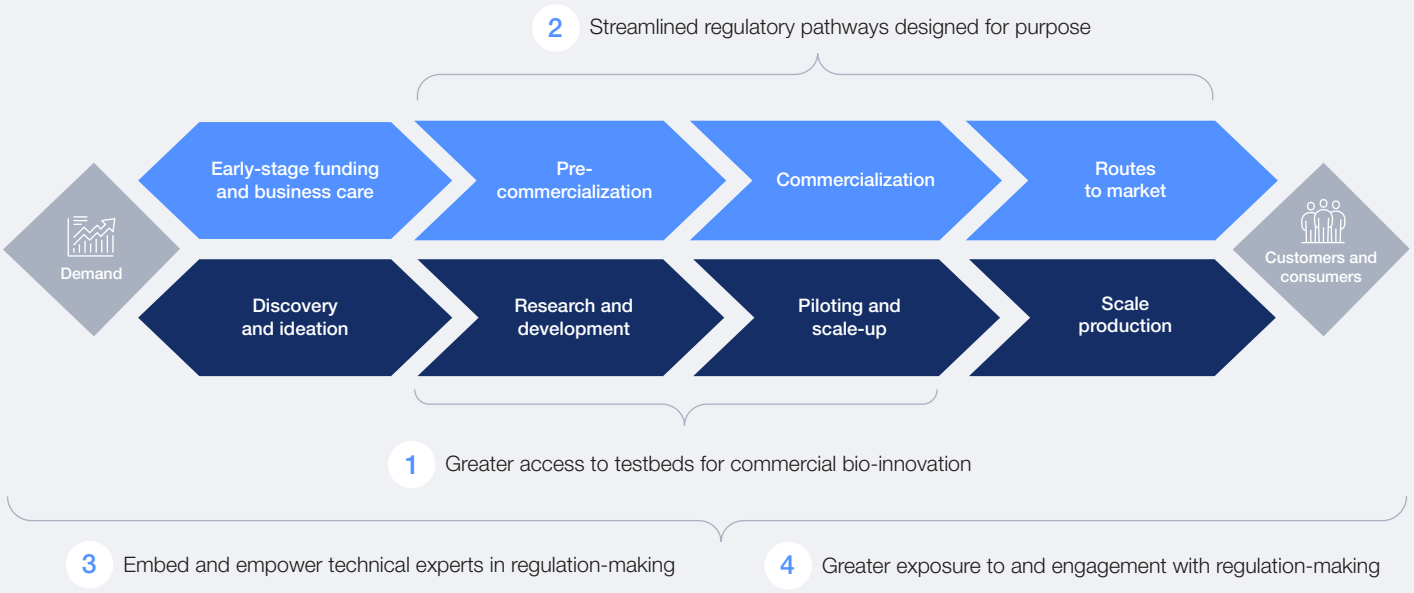
- Lack of regulatory precedence, outdated or opaque regulations that aren't fit for purpose
- Scientific expertise is underrepresented across regulatory decision-makers
- Scientific experts infrequently embedded and empowered throughout the regulation-making process
- Disparate local and regional regulatory approaches create cross-border trade conflicts for bio-based products
- Limited stakeholder exposure to regulators and the regulation-making process

Due to the complexity and fragmented nature of current regulatory landscapes, there is no one-size-fits-all solution. As a result, many commercially valuable bio-innovations struggle to gain traction, limiting their potential to deliver meaningful societal and environmental benefits.

In many cases, these innovations face unclear regulatory pathways, outdated frameworks or misaligned oversight – further constraining their impact. Without relevant and supportive guidance, their capacity to tackle urgent global challenges remains limited.

To overcome these barriers, governments must develop flexible, adaptive regulatory frameworks that protect public interests while enabling innovation. This includes empowering experts to provide timely oversight, ensuring safety and progress go hand-in-hand. Furthermore, regulation must be transparent, innovation-friendly and tailored to the unique characteristics of each advancement while also offering clear, predictable pathways for businesses to scale. To support this effort, the framework proposes four practical recommendations to help accelerate the creation of fit-for-purpose regulatory mechanisms (Figure 3).

FIGURE 3 | **Mapping category 1 recommendations to core activities connecting technology to market**



Recommendation 1

Greater access to testbeds for commercial bio-innovation

What if regulatory sandboxes became universally accessible, allowing businesses to experiment with disruptive bio-innovations under real-world conditions while ensuring safety and compliance?

As enabling technologies evolve, so do the opportunities for the bioeconomy's transformative impact. Yet, to realize their full potential, innovations must first be validated for safety, performance and efficacy in controlled, risk-protected environments such as testbeds (Box 2). Some regions have established strong testbed ecosystems, but many still lack the infrastructure needed to meet the rising demand for early-stage bio-innovation testing.

BOX 2 **Enabling safe and effective innovation: the role of testbeds**

Testbeds consist of controlled environments where new products or technologies can be tested for safety, performance and reliability before commercial deployment. Testbeds offer invaluable information to "test drive" new products without impacting external parties. Many of the phenomena observed in such testbeds cannot be identified a priori; empirical testing of these products in a controlled environment gives rise to additional safety features and product offerings that are essential for safeguarding society and delivering effective products.

Regulatory sandboxes constitute one form of testbed that allows businesses to test and experiment with new and innovative products, services or processes under regulatory supervision for a limited period of time.

Access to testbeds provides innovators with a structured environment to simulate real-world conditions, enabling products to succeed or fail faster. Controlled testing not only accelerates technology development through early failures but also reduces risk by supporting rigorous validation and evidence-based research. Additionally, testbeds stimulate market growth by allowing companies to experiment with new business models, while also informing policy and regulatory decisions.

Recommendation 1

Description

Greater access to testbeds for commercial bio-innovation will accelerate testing and iteration, increase engagement with regulators, and help bring breakthrough innovations to market more quickly.

Example

Co-funded by EIT Food and the European Union, Test Farms is a programme that empowers start-ups and individuals with groundbreaking agritech solutions to test, validate and showcase their products and services by providing ample access to real farms in Poland, Spain and Portugal.[21]

Innovation testbeds and regulatory sandboxes serve as complementary policy tools, providing flexible, forward-thinking regulatory approaches and encouraging collaboration between regulators and innovators to co-develop frameworks for emerging technologies. Expanding access to testbeds will strengthen commercial pathways, maximize societal benefits, and enable earlier, more accurate assessments of safety and efficacy.

Recommendation 2
Streamlined regulatory pathways designed for purpose

What if regulatory mechanisms were shaped at the onset to deliver innovative outcomes for humanity faster?

In today's fast-moving landscape, technological advancement often outpaces the development of regulations. This challenge is compounded by the cross-disciplinary nature of emerging bio-innovations, which frequently fall outside the scope of existing regulatory frameworks, ultimately delaying their entry into the market.

As a result, regulations often become outdated or misaligned with emerging technologies, failing to serve their intended purpose. For example, under certain EU regulations, microbes are classified as chemical pesticides, overlooking their unique biological properties and limiting their potential.[22] Persisting with outdated, misaligned regulations stifles bio-innovation, limiting consumers, patients and other beneficiaries from accessing their transformative benefits.

Recommendation 2

Description

Streamlined, purpose-built regulatory pathways will accelerate approvals, ensure relevant and effective safety testing, and help deliver the benefits of bio-innovation to society more quickly.

Example

The Regulatory Innovation Office (RIO) aims to position the UK as a global leader in innovation by creating a more agile regulatory environment, ensuring that cutting-edge technologies reach the public swiftly and safely.[23] The RIO aims to update regulations, accelerate approvals and improve coordination among regulatory bodies.

To keep pace with the rapidly evolving technology landscape, the UK's Department of Science, Innovation and Technology (DSIT) established the RIO. The RIO supports businesses in high-growth sectors by helping bring innovative products and services to market more efficiently. Acting as an intermediary between government, regulators and industry, the RIO aims to streamline approval processes while maintaining safety standards and promoting regulatory transparency and accountability.

The RIO advises the government on regulatory barriers, sets innovation-aligned priorities and helps regulators build the capacity needed to support economic growth. With a focus on engineering biology, the RIO collaborates with regulators to safely and efficiently bring bio-innovations to market. By accelerating approvals, providing regulatory clarity and minimizing unnecessary delays, the RIO aspires to cut red tape, stimulate innovation and drive economic growth – supporting business success, job creation and an improved quality of life across the UK.

Recommendation 3

Embed and empower technical experts in regulation-making

What if technical experts worked hand-in-hand with regulators to co-create dynamic, forward-thinking regulatory frameworks that evolve alongside the technologies they seek to regulate?

As bio-innovation advances, regulatory frameworks are falling behind. Embedding scientific experts within the regulatory process helps ensure that policies stay aligned with technological progress and remain fit for purpose. Their involvement strengthens regulatory agility, supports science-based risk assessments and enables faster yet rigorous approvals. By contributing specialized knowledge, experts help regulators to home in on critical scientific elements. Ultimately, close collaboration between regulators and scientists is essential for building robust, efficient and well-informed frameworks.

Integrating technical experts into the regulatory process is a common practice in various countries, enhancing the overall efficacy and relevance of regulations across sectors. With subject matter experts serving as an important resource to regulators in these regions, regulations are better poised to support the technological advances themselves.

Recommendation 3

Description	Embedding and empowering technical experts in the regulatory process will enhance the efficiency and scientific grounding of regulations.
Example	Japan's SciREX Program promotes policy "coevolution" based on the dialogue between government policy-makers and SciREX researchers.[24]

Japan's Science for RE-designing Science, Technology and Innovation Policy (SciREX) is a government initiative launched by the Ministry of Education, Culture, Sports, Science and Technology (MEXT). Its primary goal is to promote evidence-based policy-making in science, technology and innovation by integrating scientists into the policy development process. By embedding technical experts into regulatory decision-making, SciREX helps ensure that policies are both effective and well-informed, ultimately contributing to the creation of robust, data-driven policy frameworks in Japan.

Recommendation 4

Greater exposure to and engagement with regulation-making

What if every step of the regulation-making process was more transparent, providing innovators, scientists and the public with greater exposure to policies that drive progress?

Regulation affects everyone, yet pathways for businesses, consumers and civil society to gain exposure are often unclear. This opacity can undermine trust in both regulations and the processes behind them. To promote transparency across innovation and regulatory systems, stakeholders need clearer access to information and the rationale behind decisions, promoting trust and enabling more effective navigation of frameworks (Box 3).

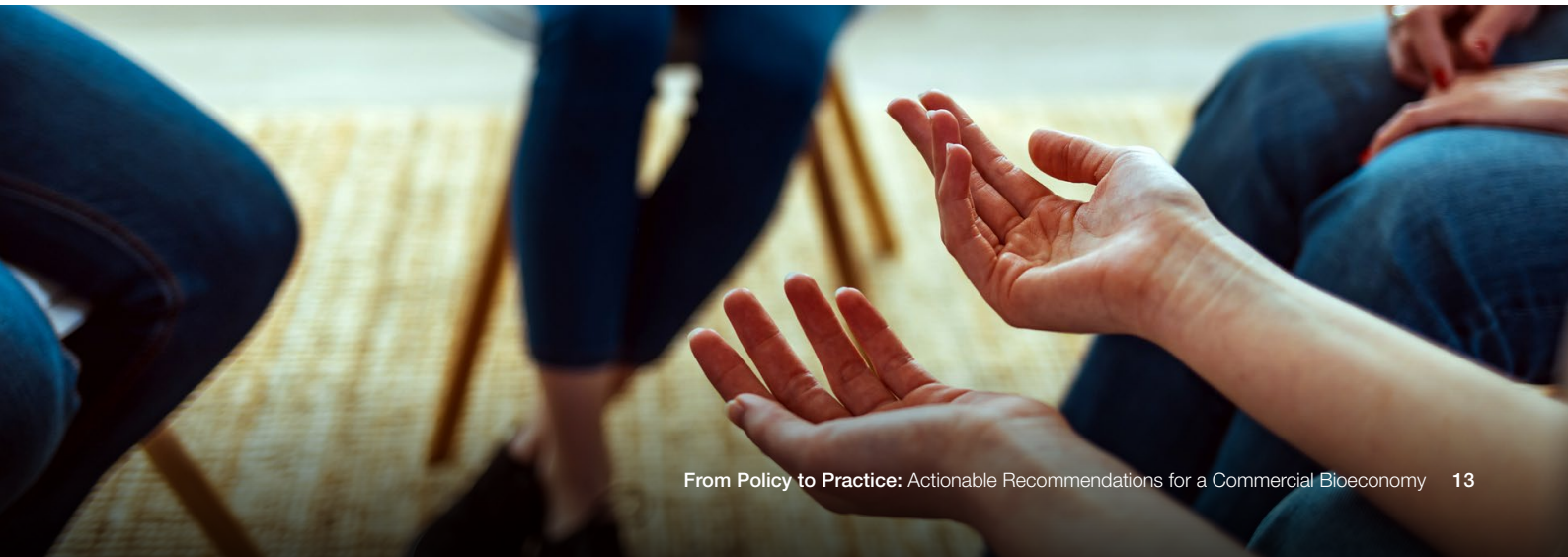
Recommendation 4

Description	Improving exposure to the regulatory process will enhance transparency for innovators and public stakeholders, build trust, and demystify the pursuit of regulatory approval.
Example	The Israel Innovation Authority's Disruptive Innovation Program provides awardees with direct and ongoing support from the Israeli Ministry of Health to navigate and facilitate regulatory processes.[25]

The Israel Innovation Authority's Disruptive Innovation Program offers early-stage companies ongoing regulatory support. By facilitating continuous communication with regulators, the programme enables more transparent and predictable decision-making. Close collaboration during R&D helps start-ups understand necessary standards and their rationale, reducing delays and minimizing misinterpretation. This proactive approach enhances transparency, mitigates uncertainty, and ensures innovation aligns with public health and safety objectives from the outset.

BOX 3 **Building trust through public consultation**

Public consultations represent another key mechanism for enhancing regulatory transparency. Inviting feedback before finalizing regulation offers several advantages: it makes the process more inclusive while strengthening the quality and effectiveness of regulations. Moreover, engaging stakeholders establishes a sense of ownership and acceptance among those most affected, thereby boosting public confidence in both the regulation and the government itself. Public consultations provide stakeholders with an opportunity to understand and respond to the reasoning behind proposed rules. In Saudi Arabia, public consultation is increasingly being used across a range of sectors to inform policies and regulations – an important step towards more transparent and participatory governance.



Summarizing framework recommendations on regulation

What we're striving for: a future where transparent, fit-for-purpose regulations are built around scientific insights and technological advances – where regulation and bio-innovations work hand-in-hand for rapid testing and iteration to deliver better outcomes for society.

Regulation is essential for ensuring safety, managing risk and protecting public well-being. Clear rules and standards safeguard individuals, communities and the environment, making regulation a cornerstone of consumer protection.[26] However, without well-defined regulatory pathways, many bio-innovations struggle to reach the market and fulfil their potential. The future of regulation does not have to mirror current challenges: these regulation-centric recommendations aim to improve commercial viability while safeguarding consumer interests. They create clear, collaborative pathways for advancing bio-innovation while promoting a more resilient future. Such a system will go a long way in supporting innovation through increased testing opportunities and expert involvement, better positioning regulations to evolve with scientific and technological advances.

Furthermore, these regulation-focused recommendations aim to improve commercial viability while protecting consumers and building trust. They create clear, collaborative pathways to advance bio-innovation and promote resilience. This system will enhance innovation through increased testing, expert involvement and adaptable regulations, providing clearer commercialization pathways. Without collaboration between innovators and regulators, rigid frameworks will continue to hinder breakthrough technologies. Regions with more efficient regulatory systems, such as faster clinical trial approvals, may outpace slower ones to widen global disparities.[27] By aligning regulatory systems with bio-innovation needs, governments can accelerate progress, strengthen protections and create the conditions for bio-innovations to scale while remaining competitive globally.

2 Incentives

Compelling incentives strengthen demand signals and drive market transformation.

As global approaches move away from top-down regulatory mandates, incentives offer a positive, proactive mechanism to drive future-oriented outcomes. They play a key role in shaping demand signals by influencing consumer behaviour, market dynamics and investment decisions. Incentives can enhance product appeal, lower barriers to adoption and align market activity with policy goals – all while allowing economies of scale to mature and reduce costs over time (Box 4).

By strategically deploying financial, regulatory, behavioural and supply chain incentives, governments and private sector actors can strengthen demand signals and accelerate market transformation. Incentives, while designed to be short-lived, provide technologists with the time to develop product-market fit, ensuring emerging technologies can drive business performance long after incentives have phased out.

BOX 4 **Incentives as a tool to drive market adoption**

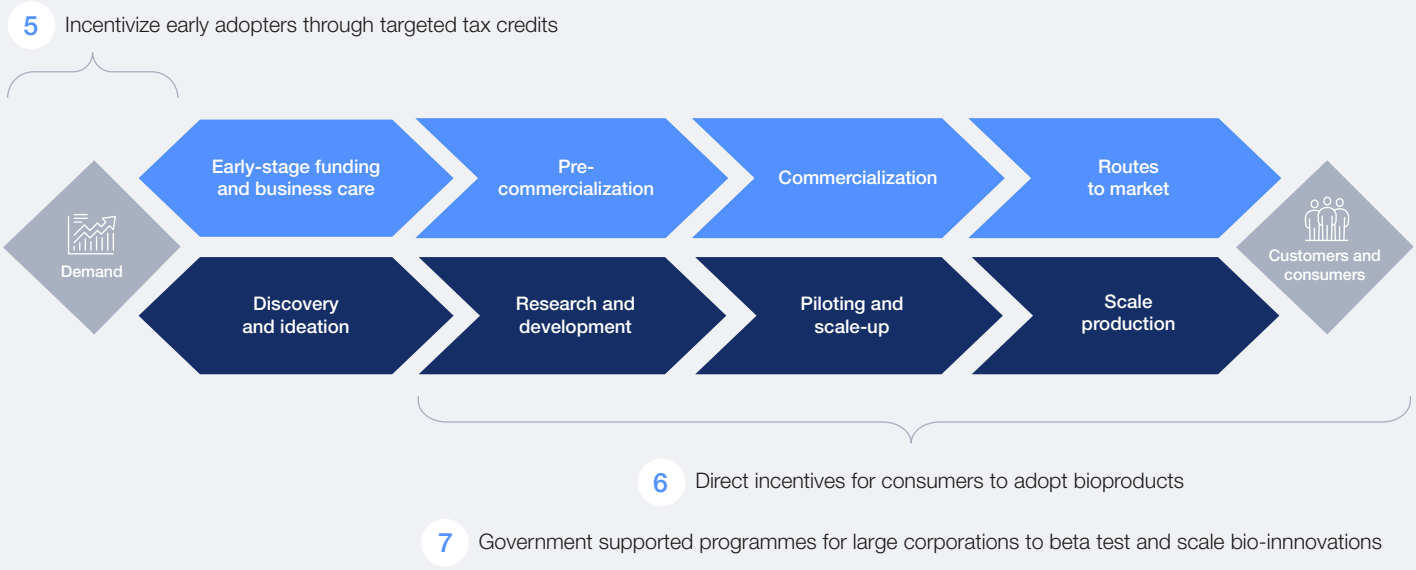
Incentives can take various forms, including tax credits, subsidies, regulatory mandates and procurement commitments. For example, during the COVID-19 pandemic, governments worldwide provided substantial funding for vaccine development and procurement, ensuring rapid distribution and widespread adoption.

Government procurement has also been used as a catalyst in programmes like the US Department of Agriculture's (USDA) BioPreferred certification that prioritizes bio-based products,[28] while Germany's public sector policies actively encourage the purchase of recycled goods and circularity.[29] These examples highlight the power of incentives in shaping market dynamics and driving adoption of innovative practices.

Few incentives have been introduced for commercial bio-innovation – and an even smaller fraction have reached commercial viability without support from incentives. The vast majority require additional financial backing and lack adequate incentive structures. As a result, many bio-innovations carry a cost premium compared to incumbent alternatives. This premium discourages adoption and investment by manufacturers, investors and consumers, despite potential transformative benefits.

Cost premiums hinder the widespread adoption and market penetration of bio-innovation. At the same time, the lack of a coordinated incentive framework limits the ability to offset early R&D and operational costs or secure guaranteed procurement – both critical for driving market uptake. Without sufficient and widespread financial incentives to offset and reduce costs, commercial adoption remains slow and uneven across sectors and geographies. A phased, government-led approach to incentivization is essential to strengthen demand signals and accelerate the global transition to a bio-based economy.

FIGURE 4 | **Mapping category 2 recommendations across core activities connecting technology to market**



To address these challenges, a comprehensive incentivization strategy should be implemented, combining financial, regulatory, corporate and behavioural incentives. While financial incentives are not practical for all governments, a phased, future-focused approach to financing is recommended – one that gradually balances funding towards bio-innovation from extractive, legacy industries. For example, in 2023 alone, the world's 60 largest lenders provided approximately $705 billion in financing for fossil fuels.[30] The specific recommendations below draw on representative examples of government incentives that have successfully driven commercial adoption and strengthened market demand.

Recommendation 5
Incentivize early adopters through targeted tax credits

What if targeted tax credits drove the future-proofing of industries with bio-innovation, incentivizing early adopters to lead the way for long-term resilience?

While government incentives to drive demand can take various forms, targeted tax credits are a successful strategy that encourage early adoption by offsetting costs and driving down cost premiums. Tax credits can deliver early cost savings for emerging technologies and provide a gateway to broader adoption across industries.

Recommendation 5

Description	Corporate tax incentives for early adopters can boost business demand for commercial bio-innovation and help usher in a market-pull era for the bioeconomy.
Example	China offers various tax incentives, including preferential rates and deductions, to encourage corporations, especially those in biotechnology and other high-tech sectors, to scale innovation and R&D.[31]

China provides a suite of tax incentives to stimulate innovation and R&D, particularly targeting high-tech sectors such as biotechnology. Corresponding incentives are designed to reduce financial burden, encourage technological advancement and enhance global competitiveness. China's reduced corporate income tax (CIT) rate for high-technology enterprises provides qualifying corporations with a reduced CIT rate of 15%, compared to the standard 25%.

By reducing the tax burden on innovative enterprises, China promotes an environment conducive to technological advancement and industrial future-proofing. China's tax incentives have significantly contributed to high-tech sector growth. In 2024, sales revenue in high-tech industries grew by 9.6% year-on-year, outpacing the overall industrial growth rate. Additionally, services related to the transformation of scientific and technological achievements into production saw a 27.1% increase, indicating a robust translation of R&D into marketable products.[32] Through the implementation of similar tax incentives, governments can accelerate adoption of bio-innovation and stimulate industry growth, thereby strengthening national positioning and competitiveness across the global bioeconomy.

Recommendation 6

Direct incentives for consumers to adopt bioproducts

What if consumer demand directly drove the acceleration of bioproducts to market through "direct-to-consumer" incentives?

With tax incentives targeted to the private sector providing one vital avenue to deliver a bioeconomy market pull, consumers represent another broad class of stakeholders that are essential to further driving demand signals. A strong demand signal from consumers is necessary to strengthen market pull. Ultimately both activities will work synergistically to strengthen signals for commercial adoption and demand. To expedite formation of a strong consumer demand signal, "direct-to-consumer" incentives will bolster demand signals and drive adoption.[33]

Recommendation 6

Description	Direct incentives for consumers to adopt bioproducts can strengthen demand signals and further catalyse a bioeconomy market pull.
Example	Aimed at helping Canadian homeowners make their homes more energy-efficient, the Greener Homes Grant offers up to CAD 5,000 (Canadian dollars) to cover the cost of eligible retrofits.[34]

While direct-to-consumer incentives specifically targeting bioproducts do not yet exist, incentives for consumers who install renewable energy infrastructure and home improvements targeting energy efficiency are gaining traction globally. In Canada, the federal grant under its Greener Homes Initiative, aimed at helping homeowners make their homes more energy efficient, was a success and fully subscribed. Solar panels, heat pumps and insulation are examples of sustainable products that fall within incentive programmes in Germany, UK and India.[35] Direct-to-consumer incentives could be applied to classes of bioproducts and services to improve affordability, ultimately strengthening consumer demand.

Recommendation 7

Government-supported programmes for large corporations to beta test and scale bio-innovation

What if large corporations were provided with targeted government support to integrate bio-innovations into their value chains?

In regions throughout the world, more governments are supporting the commercialization of bio-innovation by incentivizing companies to beta test and scale emerging technologies. More meaningful government incentives to future-proof value chains will increasingly motivate the private sector to commercially adopt and scale bio-innovation. As a result, more companies and investors will view bio-innovation as a viable and preferred option across various applications, rather than only considering it when few alternatives exist.

In some regions, governments are already supporting the commercialization of bio-innovation by incentivizing companies to beta test and scale these technologies. In particular, fiscal incentives awarded to private sector players that adopt and scale bio-innovation across their value chains can significantly encourage broader industry participation. Such programmes play a critical role in breaking the cycle of low adoption, weak demand and the technology push – helping to establish stronger market pull and accelerating the path to commercialization.

Recommendation 7

Description	Government-supported programmes that enable large corporations to beta test and scale bio-innovation will future-proof value chains.
Example	Sunbird Bioenergy's ethanol project in Zambia has received government support through a blended ethanol programme and other incentives, aiming to produce 120 million litres of fuel-grade ethanol annually.[36]

The Zambian government supported a project to scale bioethanol production to 120 million litres annually. By scaling production of renewable bioethanol together with Sunbird Bioenergy, Zambia's fuel import bill can be lowered by up to 20%, potentially saving nearly $100 million annually.[37] Overall, Sunbird Bioenergy's ethanol project exemplifies a successful collaboration between the private sector and the Zambian government to drive scaling, economic growth and energy independence. By involving industry leaders and established companies in the scaling of bio-innovation, similar programmes can drive broader adoption and market transformation.

Summarizing framework recommendations on government-driven incentives

What we're striving for: a future where government-led incentives spearhead a commercial shift increasingly fuelled by commercial bio-innovation

Incentives are key to shaping demand, influencing consumer behaviour, investment and market dynamics. By lowering adoption barriers and aligning market actions with policy goals, they help create the conditions for market transformation. To unlock this potential, governments can support a phased transition from traditional to bio-based industries, gradually rebalancing subsidies, investing in reskilling and upgrading legacy manufacturing for bioproduction. This approach reduces disruption and strengthens economic resilience.

A well-designed mix of financial, regulatory and behavioural incentives such as tax and consumer credits, subsidies and supply chain support, can drive private sector adoption and build early market momentum. Incentives are not permanent solutions but strategic, time-bound tools that help innovations scale and become cost-competitive. Ultimately, targeted incentives enhance the competitiveness of bio-based products, support a sustainable economic transition and position bio-innovation for lasting commercial success.

3 Financing

Addressing the funding gap for commercially scaling bio-innovation requires blended and creative financing.

Despite significant technological progress, scaling bio-innovation from lab to market remains a long, capital-intensive process. Too often, promising biosolutions stall in the "valley of death"– failing to translate from proof of concept into scaled commercial success. Those that reach commercial scale require substantial investment, often far beyond what traditional funding models provide.

The challenge lies in the empirical nature for programming biology; even with improved predictive tools, development timelines and associated costs remain challenging to forecast accurately (Box 5). As a result, traditional funding structures insufficiently sustain the prolonged, resource-heavy journey from bench to commercial scale.

BOX 5 **The long road to scale: lessons from bio-manufactured squalene**

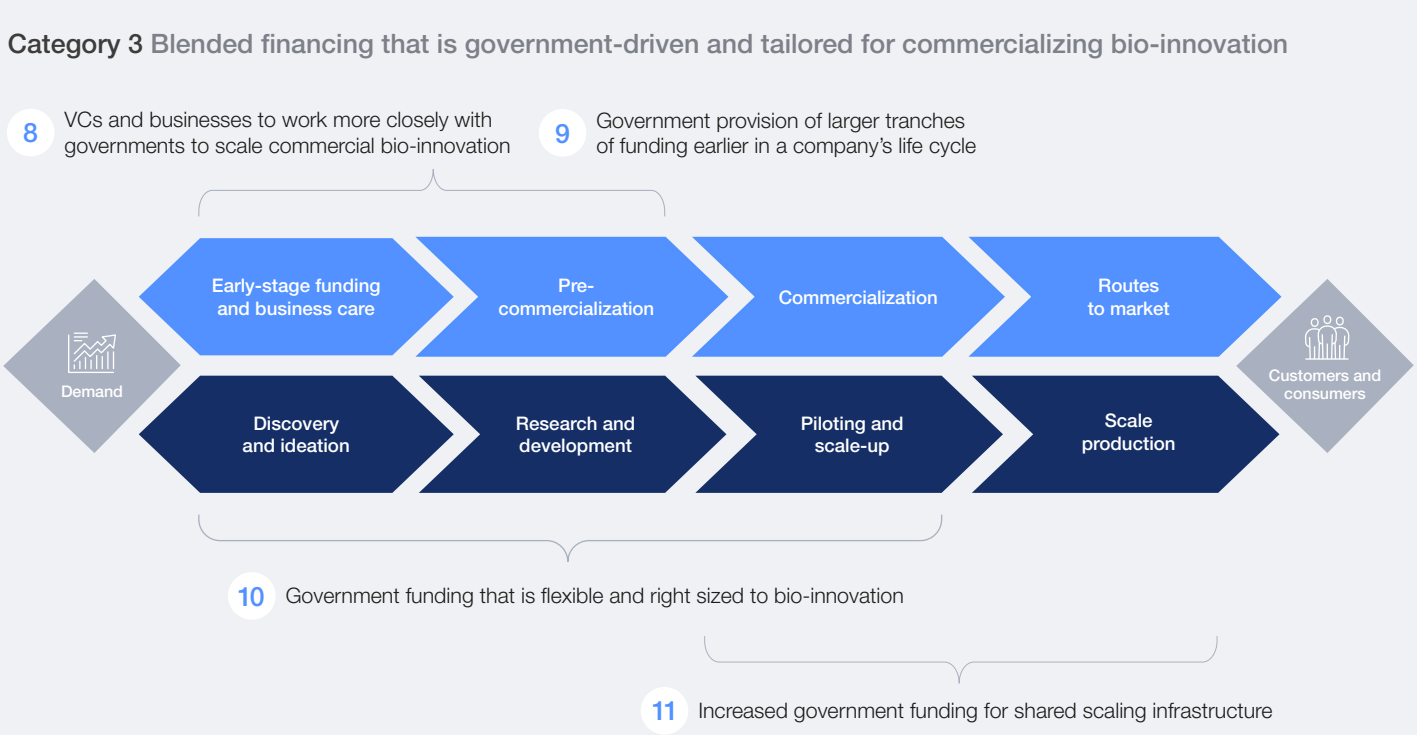
Even with the best-in-class chassis and state-of-the-art strain engineering capabilities, scaling disruptive bio-innovation takes time. Initial production of bio-manufactured squalene began in the early 2000s, but took over 10 years and considerable funding to reach significant scale.

With the squalene market valued at $169.9 million as of 2024,[38] increasing portions of the market are now relying on bioproduction. Amyris represents one example of the persistence and time required for commercial success in this space, from initial large-scale production of bio-manufactured squalane in 2011[39] to achieving 50% market share by 2022.[40] Most recently, Amyris completed a successful product sale and long-term manufacturing agreement with Givaudan in 2023 for an estimated total value of $500 million.[41]

Historically, private funding has played a pivotal role in advancing the tech-driven bioeconomy, with venture capitalists (VCs), industry leaders and private investors actively supporting early-stage companies. But as timeframes and costs increase, traditional financing structures struggle to adequately support the breadth of the scale-up journey. Significant capital needs, long development cycles and corresponding perceived risks deter investors – especially during the critical transition from pilot to commercial-scale production.

While economies of scale are gradually improving the commercial competitiveness of the bioeconomy, achieving scale remains a race against time – a challenge not always reflected in traditional financing structures. The resulting funding gap poses formidable barriers to the progress and adoption of breakthrough technologies. To mitigate risk, attract corporate partnerships and unlock adequate commercialization capital, blended financing models that combine public investment with private capital are essential (Figure 5). These approaches have already shown success in helping bio-based ventures overcome barriers to scale.[42,43]

FIGURE 5 | **Mapping of category 3 recommendations across core activities connecting technology to market**



In particular, governments are beginning to partner more closely with private sector investors, but with limited public resources there is no one-size-fits-all model, and financing gaps persist. To successfully address these challenges, tailored strategies that align with regional priorities are crucial, focusing on specific needs and harnessing local strengths. The following recommendations outline actionable pathways to strengthen and align financing mechanisms for accelerating the commercial scale-up of bio-innovation.

Recommendation 8

VCs and businesses to work more closely with governments to scale commercial bio-innovation

What if VCs, corporations and governments co-created funding models that align private sector risk with public sector support?

To build a thriving commercial bioeconomy, VCs shouldn't operate in isolation when funding bio-ventures. Increased government involvement alongside corporations and VCs in early-stage financing is crucial. Such a blended financing approach balances risk, incentivizes private investment and expands the pool of active bio-investors. Closer collaboration between governments and private investors will optimize investments, facilitate successful scaling and ultimately drive bio-innovation commercialization.

Recommendation 8

Description	Increase the use of blended and creative financing to balance risk between public and private funds and enhance overall investment.
Example	In Singapore, the government partners with private sector investors to invest in innovative, Singapore-based deep tech start-ups that have strong potential to scale globally.[44]

The Startup SG Equity scheme is a government initiative in Singapore aimed at stimulating private sector investments into innovative, Singapore-based deep tech start-ups. Spearheaded by Enterprise Singapore (EnterpriseSG) and the Singapore Economic Development Board (EDB), the programme partners with private investors to co-invest in eligible start-ups. In this co-investment model, the government collaborates with independent, qualified third-party investors, leveraging private sector expertise and capital, reducing the financial risk for all parties involved.

The scheme targets start-ups in sectors such as biotechnology and other emerging technology areas that require significant capital and time to develop.

Given the significant capital required, the government recently increased the co-investment cap to over $1 billion to support early- to growth-stage companies in validating and commercializing their technologies.[45] In this fashion, public-private partnership remains central to unlocking and de-risking investment, ensuring funds are directed in a way that benefits the entire ecosystem and the broader economy.

Recommendation 9

Government provision of larger tranches of funding earlier in a company's life cycle

What if governments invested more boldly in early-stage bio-innovation, sharing risk with private investors to fast-track breakthroughs from lab to market?

Even with increased partnership between private investors and public entities, a more balanced sharing of risks and increased support earlier in the commercialization journey is needed. While some countries offer tax credits and grants for small businesses, the public sector often offers limited financial support in the early stages of the company's development, with private investors bearing most of the financial risk.

Increasing government funding early in a company's life cycle can provide the appropriately scaled support needed to navigate the unpredictable, lengthy and capital-intensive path from laboratory research to pilot projects – and, ultimately, commercial scale. Larger public investments are essential to sharing risk and delivering targeted capital, better positioning early-stage ventures for successful translation and long-term growth.

Recommendation 9

Description	Government provision of larger funding tranches earlier in a company's life cycle will share the risk with private capital investors and increase the likelihood of reaching commercial scale.
Example	The Advanced Research Projects Agency for Health (ARPA-H) provided $25 million to Cellino, a series A company, to scale its biomanufacturing operation and bring the transformational power of bio-innovation to more patients.[46]

ARPA-H's $25 million grant to Cellino is a step in the right direction. ARPA-H is a US government agency within the Department of Health and Human Services that supports transformative biomedical and health breakthroughs. To further their mission, ARPA-H provided significant capital to Cellino in 2024 to bolster scaling efforts in developing an ultra-scalable, autonomous, cassette-based advanced biomanufacturing technology for personalized regenerative medicines. Such support will go a long way in helping this early-stage company scale its disruptive technology and bring it to more patients.

In this fashion, Cellino's NEBULA (NExt-generation Biomanufacturing ULtra-scalable Approach) project was the first project funded by the Scalable Solutions Mission Office under the ARPA-H Open Broad Agency Announcement.

While ARPA-H's support in scaling Cellino's technology is significant, earlier and more significant sums of blended capital are needed to help companies reach commercial scale. When larger, blended investments are made earlier, innovators and early-stage ventures will be better positioned to achieve commercial success.

Recommendation 10

Government funding that is flexible and right sized to bio-innovation

What if governments tailored their funding to match the pace and scale of bio-innovation, offering flexible, targeted financial solutions to empower more breakthroughs?

Over the past decade, governments have increasingly recognized the potential of the bioeconomy. Given the timelines required to scale and deliver on the full potential of disruptive bio-innovation, ultimately reaching commercial scale will require additional time, the duration of which will remain unpredictable in the immediate future.

To better position bio-innovation to meet strategic goals, governments must not only commit greater amounts of capital, but also structure investments with timelines that are realistic and appropriately sized for commercialization. In a world where governments are taking a longer-term, outcomes-based approach, funding models must evolve to become more flexible and better aligned with the unique needs of bio-innovation. Such flexibility will ensure that investment terms and support mechanisms are right-sized to overcome the inherent challenges of delivering breakthrough bio-innovations for society.

Recommendation 10

Description	Governments offer flexible, appropriately sized funding tailored to the timelines of bio-innovation to better support enterprises in reaching commercial scale, driving improved societal outcomes.
Example	SPRIN-D (Federal Agency for Disruptive Innovation) offers flexible financing timelines tailored to the unique needs of disruptive innovation.[47]

SPRIN-D, the German Federal Agency for Disruptive Innovation, is a government funding agency that supports disruptive innovations by identifying and developing research ideas with high transformative potential. Recognizing that breakthrough innovations often require flexible support structures, SPRIN-D customizes its financing timelines to align with the specific development stages and needs of each project. By offering adaptable financing timelines, SPRIN-D can effectively support projects that don't fit within traditional funding schedules, ensuring innovators receive the resources and assistance needed throughout their development journey.

Refining government funding approaches to better align with the unique needs of bio-innovation will go a long way in supporting their disruptive nature. Flexibility in timescales is essential to ensuring long-term success. Agencies like SPRIN-D exemplify effective models by providing substantial capital alongside accommodating timelines that support proving out the demonstration of disruptive technological advancement and commercial viability. These approaches help balance and share risks with private investors, ultimately creating a stronger foundation for bio-innovation to thrive commercially and benefit society.

Recommendation 11
Increased government funding for shared scaling infrastructure

What would happen if more government funds were allocated towards establishing critical infrastructure to accelerate commercial scaling?

The substantial capital costs required to scale bio-innovations, combined with long and expensive development timelines, create major barriers to commercialization.[48] While the recommendations presented so far focus on transitioning bio-innovations from the lab to commercial scale, funding for scaling infrastructure is also urgently needed. Although the number of pilot facilities supporting biosolutions' scale-up has grown significantly in recent years, access to high-quality and affordable commercial-scale pilot plants remains scarce.

The private sector alone cannot carry the burden of building such infrastructure. More is needed from governments to fund shared facilities and enable a thriving, commercial bioeconomy (Box 6). Such facilities are a breeding ground for promising bio-innovations to be taken from traditional laboratory spaces and scaled to ensure the technology can meet commercial and market demands. Further investment in shared infrastructure for piloting will increase the likelihood that bio-innovations reach the market while reducing overall capital burdens and de-risking investments.

Recommendation 11

Description	Increased government funding for domestic manufacturing infrastructure will provide better access to pilot and commercial-scale facilities, strengthening national resilience through enhanced manufacturing capabilities and supply chains.
Example	India's Department of Biotechnology (DBT) is funding biomanufacturing hubs to build infrastructure for pilot production, process optimization and the commercialization of bio-based products.[49]

The Department of Biotechnology (DBT) in India has established funding mechanisms for biomanufacturing. Under the BioE3 (Biotechnology for Economy, Environment, and Employment) policy, DBT, in collaboration with the Biotechnology Industry Research Assistance Council (BIRAC), offers financial support for pilot-scale production infrastructure, process optimization and commercialization of bio-based products. Increasing the number of pilot scale and commercial facilities will allow more companies to transition their products from the laboratory to commercial production, securing supply chains and enhancing national competitiveness for national bioeconomies.[50]

BOX 6 | **Before scaling comes R&D: how governments around the world are increasing investments in government-funded research infrastructure**

The Serbian government is set to break ground on the BIO4 Campus later in 2025. An ambitious biotechnology and biomedical research hub currently under development in Belgrade, Serbia, the BIO4 Campus will span approximately 30 hectares. It is set to become one of Europe's leading centres for life sciences, with a projected investment of €450 million – the largest science-related investment in Serbia's history.[51]

In Saudi Arabia, the Research Development Innovation Authority has implemented a national policy to enhance access to government-funded research infrastructure, including national laboratories. The policy promotes open access to government-funded research infrastructure, allowing external users (local and international) to conduct research, development and innovation activities.[52]

In the Eastern Hemisphere, the Kenya Biovax Institute has been established to support local vaccine production and bio-innovation.[53] Positioned as a regional centre for life sciences manufacturing, the institute is part of Kenya's broader strategy to build health sovereignty, drive biotech R&D, and reduce dependence on imported vaccines and biopharmaceuticals.

Recently, governments are increasingly developing partnerships to build key infrastructure. For example, in Taiwan, China, the government has teamed up with National Resilience to form Taiwan Bio-Manufacturing Corporation (TBMC). Following a model similar to Taiwan Semiconductor Manufacturing Company (TSMC), which was founded with government support and is now the world's largest chipmaker, TBMC will use the country's expertise in smart manufacturing and digital tech to produce cutting-edge biomanufacturing solutions for complex medicines like biologics, vaccines and gene therapies.[54] Globally, infrastructure will continue to serve as the backbone of a thriving, resilient bioeconomy, the establishment of which requires significant financial support from governments and beyond.

Summarizing framework recommendations on blended and right-sized financing

What we're striving for: a future where transformative bio-innovations rapidly move from bench to market, powered by creative and blended capital that matches the pace, risk and capital needs of scaling breakthrough bioscience.

Currently, too many promising bio-innovations fail to successfully navigate the "valley of death", the gap between lab success and commercial viability. To address this, governments must intervene earlier, committing larger investments at initial stages to balance risk and attract private capital. These investments must be flexible and appropriately sized, considering the lengthy and unpredictable development timelines and substantial capital demands of bio-innovation.

In addition to funding individual companies, increased public investment in scaling infrastructure, such as pilot facilities and biomanufacturing hubs, is urgently needed. Proactive collaboration between governments, corporations and VCs will align risk tolerance and further enable scaling of disruptive bio-innovation. Ultimately, bridging the commercialization gap requires innovative capital models that combine public and private funding sources and are tailored to the unique needs of bio-innovation. Financing is not just a support tool; it is the strategic lever that will unlock the full potential of the technology-driven bioeconomy.

4 Access and education

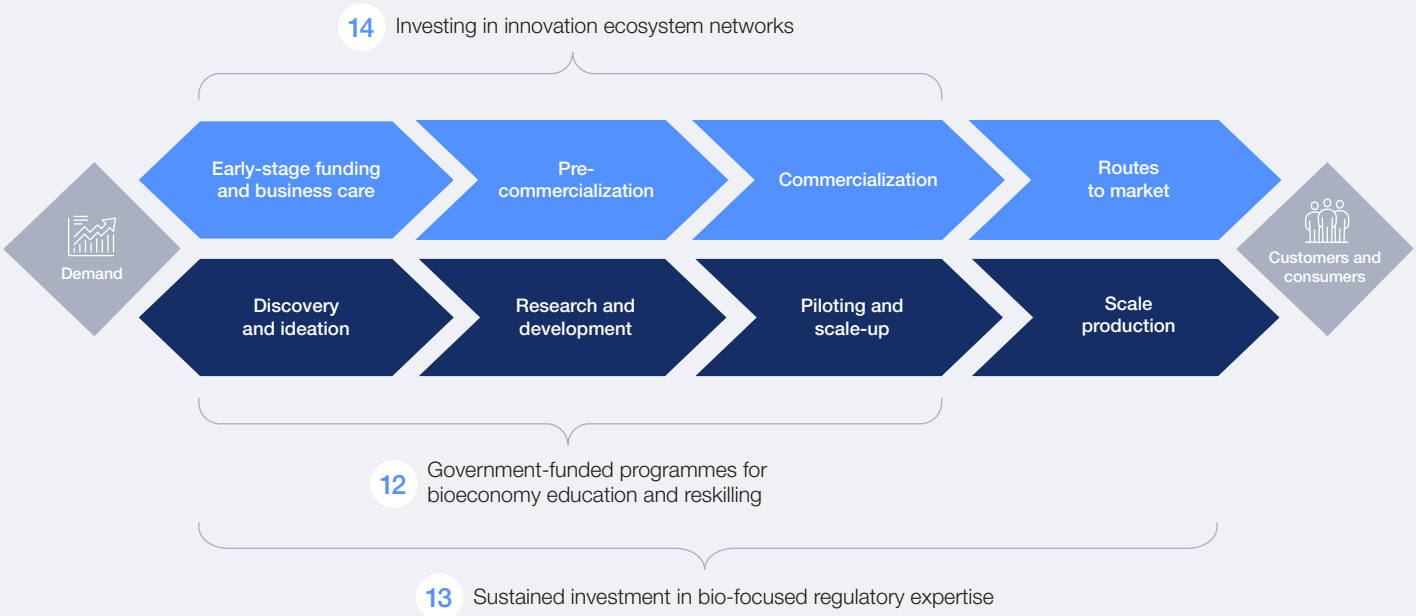
Prioritizing education and reskilling efforts across an interconnected innovation ecosystem will grow a technically skilled, future-ready workforce.

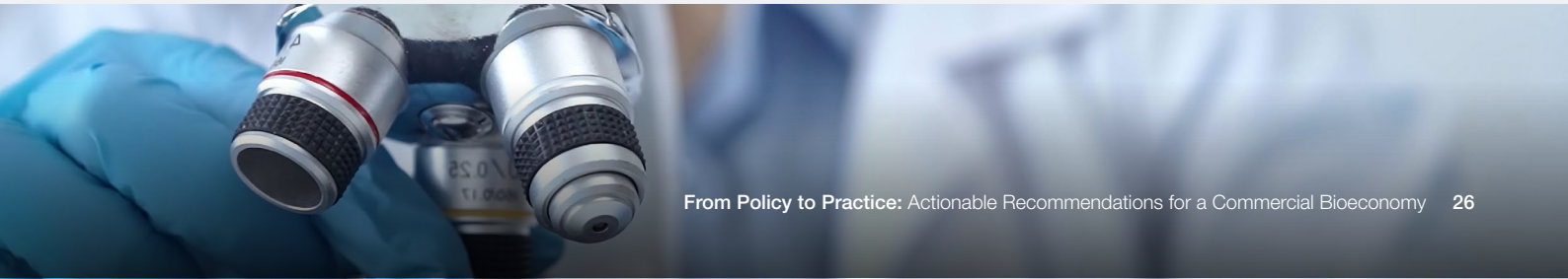
To proactively prepare the workforce for emerging industries, governments must devote increased attention to reskilling and education. The rapid pace of technological advances, particularly in engineering biology, bio-manufacturing and convergent digital technologies, necessitates a workforce that is not only technically skilled, but also adaptable to new tools, techniques and regulatory frameworks. As the sectors giving rise to the bioeconomy evolve, the demand for diverse and interdisciplinary skills, from molecular biology and chemical engineering to computer science and regulation, will become even more crucial.

Providing infrastructure and real-world training facilities that support continuous learning and collaboration is essential for promoting workforce adaptability. Innovation ecosystems play a critical role by offering educational and professional training programmes across all levels. Through specialized vocational training and reskilling initiatives delivered via local and regional hubs, these interconnected ecosystems provide the necessary infrastructure to prepare the workforce for the future in an industrially relevant setting.

The establishment of thriving innovation ecosystems will not only support the growth of a highly skilled and resilient workforce but also drive expansion of the bioeconomy itself. The three following recommendations focus on strengthening innovation ecosystems to improve access to essential infrastructure and equipment, enabling their use for critical training, education and reskilling efforts. By strengthening focus around education and reskilling, as well as the establishment of a broader and interconnected innovation ecosystem, governments can drive economic transformation, stimulate job creation and position themselves as global leaders in the bioeconomy (Figure 6).

FIGURE 6 **Mapping of category 4 recommendations across core activities connecting technology to market**





Recommendation 12

Government-funded programmes for bioeconomy education and reskilling

What if investing in bioeconomy education today gave rise to a workforce that is skilled, agile and primed to deliver a prosperous and resilient future?

Increasing government funding for bioeconomy-focused education and training programmes will ensure that workers at all levels – whether in research, manufacturing or regulatory roles – are equipped with the necessary knowledge to thrive in such a rapidly evolving sector (Box 7). This investment will help bridge the skills gap, ensuring talent is available to meet the growing demand for commercial biosolutions and that workforces remain competitive in the global economy. To that end, government-funded biomanufacturing facilities for pilot and commercial scaling will provide an important environment for workforce training and re-skilling. The spillover effects of such investments on employment in the bioeconomy workforce are also significant – each job in industrial biotechnology is estimated to generate 3.4 additional jobs in the bioeconomy.[55]

Recommendation 12

Description	Government-funded programmes focused on bioeconomy education and reskilling will deliver a resilient, future-oriented workforce.
Example	CNPq and the Brazilian National Service for Industrial Training (SENAI) in Brazil fund vocational training in biofuels, biomaterials and agribiotech, and have established technical centres to develop the bioeconomy workforce.[56]

A prominent example from Brazil is the collaboration between the National Council for Scientific and Technological Development (CNPq) and SENAI. Together, they fund vocational training programmes in biofuels, biomaterials and agribiotech and build technical training centres for bioeconomy workforce development. Through these efforts, CNPq and SENAI have been instrumental in developing a skilled workforce and advancing technological innovation within Brazil's bioeconomy sector.

BOX 7

Cross-border collaboration: democratizing access to advanced biofoundry knowledge and education

Nations are collaborating across borders to co-lead a certification programme aimed at bolstering the biofoundry workforce. The Engineering Biology Research Consortium (EBRC) along with nations such as the UK, Finland, Japan and South Korea will build on the Global Center for Biofoundry Applications (GCBA) past experience with online education to develop a Massive Open Online Course (MOOC). Aiming to democratize access to advanced biofoundry knowledge and support a global community of skilled synthetic biologists, each partner will participate in the development of course modules such as biofoundry design, laboratory automation, DNA synthesis and assembly, genetic engineering, bioinformatics, artificial intelligence (AI) and machine learning (ML), data analysis, governance, regulations, ethics, biosafety and biosecurity. Resulting courses feature guest lectures by prominent global scientists and industry leaders, and corresponding discussion forums will enable participants to form study groups, ask questions and further develop ideas.

Recommendation 13

Sustained investment in bio-focused regulatory expertise

What if dedicated career pathways for regulatory bio-experts were prioritized to ensure the workforce evolves alongside cutting-edge scientific advancements?

Regulatory frameworks must evolve with technology to ensure public safety without hindering progress. The importance of governments to recruit, retain and train regulators to keep pace with the rapid advancements in science and technology cannot be overstated. One path to meaningfully integrating experts into the regulation-making process involves not only how regulators are trained and recruited, but also the creation of reciprocal mechanisms that enable scientists to gain regulatory experience. Bioeconomy-tailored curricula will help prepare regulators to stay abreast of technological advances, while ensuring regulations are right-sized to support commercialization and maximize societal impact.

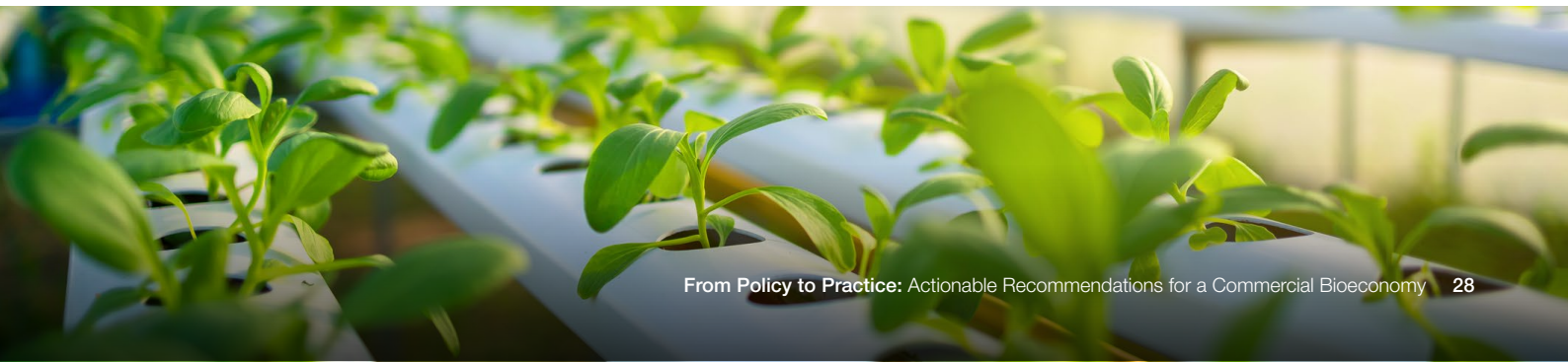
Recommendation 13

Description	Sustained investment in bio-focused regulatory expertise will ensure that both regulators and scientists are equipped with the knowledge needed to create effective, agile frameworks designed to keep pace with innovation.
Example	The International Service for the Acquisition of Agri-biotech Applications (ISAAA) provides an intensive training programme on agricultural biotechnology, biosafety regulation and effective communication.[57]

In one example from Thailand, the International Service for the Acquisition of Agri-biotech Applications (ISAAA) offers training programmes and educational events for scientists and regulators focused on agricultural biotechnology, biosafety regulation and effective communication. The potential of bio-innovation to drive more resilient agricultural practices relies not only on R&D but also on integrating key elements such as science-based regulatory frameworks, effective communication strategies and a comprehensive understanding of legal instruments. These factors are essential for the co-evolution of science and regulation, enabling society to responsibly benefit from game-changing bio-innovation.

By investing in the continuous education and professional development of regulators, governments can equip regulatory professionals with the necessary technical expertise and knowledge to navigate complex, fast-changing advances. Alternatively, scientists can be given additional opportunities and entry points to regulation-making processes. Government-led open innovation offices are actively supporting such training; one instance in particular, hosted by ASEAN-UK,[58] incentivizes scientists by providing additional accreditation for students.

Formalized training not only works to enhance the effectiveness of regulations but also ensures that regulators can make informed decisions that balance innovation with public interest. Furthermore, retaining skilled regulators and reskilling scientists to become regulatory experts promotes continuity and stability in regulatory bodies, which is critical for maintaining trust and confidence in the regulatory system. In an era of rapid technological change, well-trained, adaptive and scientifically-minded regulators are essential for ensuring that bio-innovation advancements continue to safely and responsibly benefit society.



Recommendation 14

Investing in innovation ecosystem networks

What if networks were established across technology hubs to build ecosystems of innovation that opened doors and fast-tracked local innovations into scalable global solutions?

While additional financing is still needed to expand government-established pilot and commercial manufacturing capacity, some governments have made significant progress over the past decade in building out such infrastructure (Box 8). These facilities not only help alleviate the persistent shortage of capacity, which is often oversubscribed, but also serve as critical training grounds for workforce development and reskilling.

BOX 8 **Bolstering bioindustrial manufacturing infrastructure: BioMADE's $432 million investment**

In the US, the BioIndustrial Manufacturing and Design Ecosystem (BioMADE) funds projects that support innovation and scale-up using a combination of federal funding and non-federal cost share.[59] Recent investments of over $200 million from the US Department of Defense and the Minnesota Department of Employment and Economic Development will support the development of pilot- to demonstration-scale bioindustrial manufacturing infrastructure. These multi-user sites in California and Minnesota will form part of a network that allows companies to transition their products from laboratory to commercial production, securing supply chains and enhancing national competitiveness for the US bioeconomy.[60,61,62]

While some governments have invested in scaling infrastructure, many countries lack access to pilot and commercial-scale facilities. In these regions, building such infrastructure locally can be impractical or economically unfeasible. Establishing a coordinated network of innovation ecosystems, across existing pilot and scaling facilities, with a pronounced focus on expanding access, will provide critical capabilities and equipment to underserved areas while bolstering the individual capabilities and offerings of each facility. This approach offers a practical solution for both governments and bioscience ventures, and simultaneously supports workforce development and scaling of commercial bio-innovation.

Building networked access across technology hubs to establish an interconnected innovation ecosystem would not only provide ample training grounds for bioeconomy education and reskilling, but would also support broader collaboration and knowledge sharing while democratizing innovation across regions. Through connecting entrepreneurs, students, researchers, policy-makers and investors, these hubs would create a robust ecosystem that supports start-ups and academic institutions with additional resources, mentorship and technical expertise while expanding access across this powerful network.

Recommendation 14

Description	Investing in innovation ecosystem networks will enhance national competitiveness and expand access to pilot and commercial-scale infrastructure globally, while also serving as key hubs for education and workforce training.
Example	South Korea's Bio-Great Transformation Strategy seeks to integrate 20 bioclusters nationwide, enabling collaboration and infrastructure sharing.[63]

South Korea's Bio-Great Transformation Strategy is a nationwide initiative aimed at enhancing the country's biotechnology sector by integrating approximately 20 existing bioclusters into a cohesive network, thereby forming an interconnected innovation ecosystem at the national level.

Through this interconnected network, the Bio-Great Transformation Strategy seeks to promote collaboration and share infrastructure among clusters, strengthening South Korea's global positioning in commercial bio-innovation.

To launch the initiative, the newly formed National Bio Committee will coordinate policies across ministries to support public-private collaboration in areas such as health, medical care, food, resources, energy and the environment. The committee aims to create a unified bio data platform, establish advanced computing infrastructure, and train 110,000 professionals in the bio-health field by 2027. By connecting these bioclusters and promoting resource sharing, South Korea intends to enhance their positioning as a global leader in commercial bio-innovation by 2035.[64]

Linking government-funded facilities into broader innovation ecosystems enables collaboration, drives bio-innovation and builds strong regional capabilities. These hubs not only attract local and international talent but also support the development of skilled workforces in multiple regions, including those without dedicated government infrastructure.

Expanding access across innovation ecosystems promotes regional development through job creation and supports economic growth, particularly in underserved areas (Box 9). A coordinated network approach can enhance access to funding, markets and policy support, while enabling a more diverse, competitive and inclusive innovation landscape.

Making facilities more accessible, alongside targeted outreach and scholarship programmes, will broaden participation, making the bioeconomy more equitable globally. Furthermore, investing in affordable, modular infrastructure, such as biofoundries outside traditional tech centres will empower regional talent and build localized access to innovation tools and expertise.

Together, these efforts will strengthen supply chain resilience, prepare nations for future challenges and accelerate the bioeconomy, advancing both economic progress and global competitiveness.

BOX 9

US National Science Foundation BioFoundries investment

A notable example of government investment in biofoundries is the US National Science Foundation's (NSF) initiative to establish five new biofoundries, with a total investment of $75 million.[65] These facilities aim to democratize access to advanced biotechnology infrastructure, providing researchers nationwide, ranging from community colleges to research-intensive universities, with tools and technologies to advance biology, biotechnology and bioengineering. The NSF BioFoundries will operate as user facilities without charging user fees, facilitating innovation across various sectors, including AI, health and climate resilience. Additionally, the NSF is collaborating internationally to create global centres that will employ biofoundries to accelerate R&D in the bioeconomy.

Summarizing framework recommendations on innovation ecosystems

What we're striving for: a future where governments establish interconnected innovation ecosystems that expand access to training and facilities, promoting a technically skilled, adaptable workforce while strengthening bioeconomy capabilities.

Access and education will be vital to the success of the bioeconomy and can be facilitated through the networking of individual centres and hubs into interconnected, nationwide innovation ecosystems. Successfully interconnecting individual hubs will increase access to training and educational resources. The interconnected nature of these facilities, combined with democratized access, will work towards delivering an equitable bioeconomy and driving meaningful progress while producing a steady stream of well-trained professionals and regulatory experts.

By enabling wider demographics to access a global network of critical research and commercial infrastructure, companies will benefit from increased opportunities to pilot and scale bio-innovations with fewer constraints around their financial resources or geographical location. Robust innovation ecosystems encourage valuable public-private partnerships (PPPs) and support a unified approach to the development, training and commercial implementation of bio-innovation.

The long-term success of bio-innovation hinges on the establishment and continuous support of a workforce that evolves in both size and capability. Developing and maintaining a skilled, adaptable workforce is essential for global competitiveness, as well as for the reskilling of present and future workforces. Introducing a bi-directional education model between scientific and regulatory communities is key to enabling the co-evolution of science and regulation. Such an interconnected, multifunctional foundation will be vital to accelerating a successful, transparent and trusted commercial bioeconomy.

Concluding remarks

During periods of rising geopolitical tension, balancing global trade uncertainties with resilient supply chains is more crucial than ever. With a promise to reshape global industries and bolster national competitiveness, the bioeconomy holds the potential to strike this important balance.

The capacity for the bioeconomy to deliver future-oriented industrial transformation is significant. Enhanced manufacturing capabilities from thriving bioeconomies provide nations with greater supply chain certainty and a national competitive edge. Governments worldwide are capitalizing on these opportunities, with more than 50 national bioeconomy strategies now in place.

Yet, despite significant technological advancements, commercial bio-innovation remains on the fringes of mainstream adoption; biosolutions are too often conceived without a comprehensive "beyond the bench" framing, neglecting to take into consideration the full context of the commercial value chains they strive to complement. A shift from leading with the technology to a market-pull approach is necessary to ensure bio-innovation is not only scientifically sound but also commercially viable.

In parallel, enabling policy frameworks are essential to unlocking growth. The complexity and diversity of bio-based industries has led to regulatory uncertainty, ultimately creating barriers to scale. Streamlining approval processes, providing compelling fiscal incentives and capital that is "right-sized" for commercial bio-innovation, as well as improving access to reskill the bio workforce will reduce friction and streamline the process of commercialization, enabling bio-innovations to move from research to real-world application more efficiently.

In a concerted path forward, governments and industries must work together to send strong, consistent market signals that encourage private sector participation. Governments, industry leaders and innovators must convene to translate action-oriented recommendations into tangible alliances and outcomes. Targeted policy dialogues represent an important tool to further home in on region-specific barriers and opportunities.

With numerous national strategies already in place, this framework provides a concrete foundation for policy-makers to take action. Without strategic interventions, the bioeconomy risks remaining fragmented and abstract, rather than becoming a transformative force for good. The proposed recommendations emphasize key actions to drive progress: modernizing regulations, introducing meaningful incentives, creating innovative financing mechanisms, and investing in education and national innovation networks. By implementing these measures, bio-innovation can begin to realize its full potential across industries, not just across niche and historical markets. Moreover, through diversifying sourcing, investing in innovation and strengthening strategic partnerships, governments and businesses can overcome trade challenges to secure a thriving and resilient future for all.

The bioeconomy is no longer a distant vision: it is an emerging reality. However, its full benefits will only be realized through decisive action and coordinated efforts. By implementing the recommendations outlined in this framework, policy-makers and industry stakeholders can ensure that bio-innovation becomes a cornerstone of economic growth and resilience, sustainability, and global competitiveness. The time to act is now.

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